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DIAGNOSING THE NITROGEN AND MINERAL ELEMENT REQUIREMENTS  
OF GREENHOUSE VEGETABLE CROPS BY MEANS OF FOLIAR ANALYSIS

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The establishment of the foliar analysis program for the purpose of ascertaining the nutrient element status of vegetable plants produced in commercial greenhouses in Ohio on July 1, 1964, was the culmination of 20 years of research. Tomato, cucumber, Bibb and leaf lettuce are included along with 13 other vegetables growing under field environment. Since initiation of the program the results have greatly exceeded the expectations current at the time of its formulation. It has been possible as never before has been the case to evaluate the possible role of a given nutrient element or combination of elements in restricting growth and yield. This information is obviously of great importance since so many other factors such as air temperature, light intensity, water supply, soil aeration, insect and disease damage and the like are often the detrimental factors rather than a deficiency or an excess of an essential nutrient element.

Experimental Background of Program

In 1944 an extension survey of the nutrient elements by means of soil and leaf analyses in more than 35 commercial greenhouse establishments located in every section of the state was carried out. A wide range in composition of the various elements was ascertained and interestingly enough differences in yields were observed to be due largely to management rather than to a deficiency or excess of any particular element. In conjunction with and for several years thereafter an extensive experiment was set up in three commercial greenhouses with data on both yield and leaf composition. In the above listed experiments leaf composition was usually obtained at successive intervals from different

locations on the plants concerned.

As a significant part of the experimental work conducted in the greenhouses of the Department of Horticulture during the 1960-1964 period involving different water and air temperature treatments, as well as carbon dioxide involvement, leaf composition has been obtained. During 1964 a factorial experiment (Box-Wilson design 4) was initiated involving varying increments of nitrogen and potassium was initiated in these greenhouses in order to ascertain in particular their effect upon such fruit quality defects as puffiness, cracking, bursting of the fruits, the occurrence of off-color, off-shaped or malformed fruits, fruit composition and other indices of plant and fruit reaction to treatment.

It must also be pointed out that during the last 15 years a considerable amount of leaf analysis has been conducted in connection with the occurrence of disturbances in plant growth and fruit development in commercial greenhouses. By this means it has been possible to ascertain very satisfactorily the extent to which chlorosis, and the like, have been brought about as a result of either a deficiency or an excess of an essential nutrient element, and finally over the last 15 years gravel and perlite have been utilized for nutrient element experiments in connection with graduate student instruction at The Ohio State University. As a result of this wide range of work involving composition of leaves at all locations on the plant and under widely varying environmental conditions the decision was reached to initiate the formal program for commercial greenhouse vegetable producers.

#### Elements Analyzed and Methods Utilized

During the early years phosphorus was obtained by the molybdenum blue method while potassium, sodium, calcium and magnesium were analyzed with

the Beckman Spectrophotometer. The micronutrients were obtained by the usual chemical methods. Beginning in 1956 a B and L Spectrograph was utilized. Beginning in 1964 a direct reading Mass Spectrograph was purchased which has permitted the addition of zinc and aluminum to the list of elements now being obtained. Nitrogen is analyzed by the Kjeldahl method. The data from the typewriter are forwarded to the statistical laboratory which decides the results and prints them on the appropriate forms showing composition in percentage on the dry weight basis and parts per million. These data are forwarded to the producer along with the interpretation.

The results become available to the grower within 7 days after receipt of leaf samples which are accompanied by a rather detailed questionnaire giving pertinent information relative to variety treatment, mulches amount of fertilizer applied, soil test results (if available) and the like. The leaf samples are taken at precise location on the plant according to directions with the aid of the County Agricultural Agent where this is necessary. The success in obtaining complete statements on the part of producers has been excellent. The results of the interpretation are frequently phoned to the producer in order that he may withhold or apply particular nutrient elements as suggested by the results of the analysis.

The actual data for each element are reported under one of the following categories, deficient, low, sufficient, high and excess. Obviously each of these categories has been defined specifically. Deficient represents values which are usually so low that visual effects are noted, such as chlorosis or necrosis of leaves. Low is the category in which presumably growth and yield are adversely affected but chlorosis for example has not resulted. In terms of critical level both categories are considered below this level.

Sufficient represents what might be considered near optimum and definitely above the critical level. High includes those amounts of considerable magnitude but not detrimental. The exception here is nitrogen, which in this category would be considered approaching an unfavorable effect upon growth and yield. Excess in all items includes the amounts considered to be detrimental even if no visual indications are necessarily recognizable or present.

In connection with the separation of leaf composition values into these categories, the range of composition of leaves of a given species extending from the lowest to the highest magnitude has been ascertained for every element as a result of the experimental work indicated previously. For example the values for potassium in the tomato leaves have ranged from 0.5 to 15.0 percent on the dry weight basis. The range in composition in the deficient category has likewise been reasonably well ascertained. The magnitudes of the critical values for each element is based upon the results of the experimental work conducted in conjunction with the results obtained by other investigators with these particular crops whenever such data have been presented. Obviously, the magnitude of such elements are nitrogen, phosphorus, and potassium depends upon the location of the leaf samples on the plant. The importance of standardization of sampling techniques in this connection cannot be over-emphasized. In this program the more mature basal leaves of tomato and cucumber are selected. Both the entire above-ground portion of lettuce are analyzed. It should be stated in passing that although rather definite critical values are utilized in interpreting the results, small variations in either direction are not of disturbing import. For example, although 0.2% D.W.B. is taken as the critical level for phosphorus whether or not this is influenced by the magnitude of nitrogen to a range of 0.1 to

0.3% is not considered detrimental to the program since actually the highest content of phosphorus has been found to be an excess 1.0 percent. Usually visual symptoms on the foliage do not occur until the lower magnitude becomes less than 0.1 percent.

#### Major Results of Foliar Analysis

Analysis of leaves during the experimental work has produced some major results of which mention of only a few can be presented here.

#### Variation Patterns

Analysis of the tomato leaves has indicated that rather definite patterns of composition of each element may be expected from the basal mature to the tip most immature leaves depending upon the magnitude of the deficiency or excess of the element concerned. With this information it is possible to a reasonable degree to project or estimate the composition of leaves either proximate or terminal to the leaf analyzed. Obviously much more is to be discovered in this connection, but the reproducibility of results in leaves taken under widely varying circumstances and environments supports this conclusion. Were this not true, it would be necessary to obtain samples from all locations on the plant in order to conclude as to the status of a given nutrient element. This is not meant to infer that locations of leaves sampled should not be standardized, since obviously the precise critical level utilized will depend upon leaf location. Yet a knowledge of the accompanying probable composition of more mature distal leaves permits one to make some reasonable assumption of the nutrient element status when sampling location differed from the recommended position.

#### Nitrogen Leaf Content

Excessive rather than deficient nitrogen is frequently found in green-

house tomato plants. This result may be expected in view of the amounts and frequency of application of this element as well as the composition of the peanut hulls utilized frequently as mulch. It has been found that even when yield was not affected by soil applications of nitrogen yield was negative and quality defects positively correlated with leaf nitrogen.

Nitrogen occupies as is well known a dual position in the tomato. Obviously too low nitrogen as well as excessive nitrogen is detrimental to yield and quality. The precise range of leaf nitrogen between these two extremes seems to vary from month to month depending on various other environmental factors. This area requires much more research but sufficient is known at present to permit certain tentative workable standards of leaf composition. These are being used to induce a reduction in the amount and frequency of nitrogen applications during these periods of the year when the days are relatively short and light intensity somewhat below optimum.

#### Phosphorus and Potassium Status

In the Ohio greenhouses phosphorus and potassium have been found to range from sufficient to high. Not infrequently potassium is excessive reaching values in excess of 11 percent (D.W.B.). The tendency to apply very liberal amounts of these nutrient elements during the year has resulted in this situation. Under some conditions the potassium excess is believed to be detrimental even apart from the magnesium deficiency induced. Evidence being obtained in connection with the N/K experiment initiated in 1964 indicates that excessive potassium may be positively correlated with certain fruit quality defects.

#### Potassium-Induced Magnesium Deficiency

One of the outstanding effects of excessive potassium as might be

expected is the induction of magnesium deficiency. Fortunately, unless such deficiency occurs early in the life of the plant no visible detrimental effect upon total yield can be observed. That accompanying changes in fruit composition result is probable but as yet these have not been clearly defined.

#### Micronutrient Supply Usually Abundant

Regardless of soil pH and other related factors the amounts of manganese, boron, iron, copper, molybdenum and zinc have almost invariably been found to be abundant. This is true both in the experimental work as well as in the results of the leaf analysis program. Presumably the large amount of mulching material applied together with other organic material is responsible for maintaining more than an adequate supply of micronutrients despite the fact that such pH very frequently exceeds 7.0. Obviously such a situation greatly simplifies the micronutrient interpretation with these greenhouse vegetable crops.

#### Manganese Toxicity

Manganese toxicity has occasionally been obtained following steaming of new soils containing large amounts of naturally-occurring manganese. Furthermore the rather long steaming periods frequently carried out have been conducive to leaf manganese contents exceeding 3000 and reaching 5000 parts per million. Usually visual symptoms do not occur until 4000 ppm are attained. An outstanding result of the leaf analysis dealing with the effect of N/K relationships upon fruit quality has been the positive correlation (170 part) between leaf manganese and off-color in tomato fruits. In these instances manganese did not exceed 600 ppm.

### Final Conclusions

The establishment of the leaf analysis program has not only been of outstanding practical importance to the producer of greenhouse vegetable crops but is also an exceedingly valuable adjunct to the accompanying research work. By this means it is possible to compare results and to develop more precision in the grower program. On the other hand, the results becoming available by analysis of plants in commercial greenhouses serve as a guide to future research in plant nutrition.

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